Journal of Environmental Protection and Ecology 2, No 2, 299–303 (2001)

Environmental radioactivity

PHYSIOLOGICAL RESPONSE OF BEANS (*Phaseolus vulgaris* L.) TO GAMMA-IRRADIATION TREATMENT. I. GROWTH, PHOTOSYNTHESIS RATE AND CONTENTS OF PLASTID PIGMENTS

N. STOEVA[a*], TZ. BINEVA[b]

[a] *Agricultural University, 12 Mendeleev Street, 4000 Plovdiv, Bulgaria*
E-mail: stoeva@au-plovdiv.bg
[b] *Institute "N. Pushkarov", 7 Shousse Bankya Street, Sofia, Bulgaria*

Abstract. The aim of the current research was to study the tolerance of young plants of two cultivars beans to gamma-irradiation stress. For this purpose, the dry bean seeds of cultivar Plovdiv 10 and Plovdiv 11 were irradiated by gamma-rays Co^{60} with doses of 150 and 200 Gy. On the 30th day of their development, an analysis of the growth of the plants, the leaf gas-exchange, and the contents of plastid pigments was done. The results of the research show that the applied irradiation doses of 150 and 200 Gy inhibit the basic indices for growth analysis, depending on the irradiation dose, and this is most evident in cultivar Plovdiv 11. The gamma-irradiation suppresses the leaf gas-exchange in bean plants and at 200 Gy the transpiration inhibition is from 26 to 39%, and that of the photosynthesis is from 33 to 38%. The data on the changes in the plastid apparatus do not differ significantly from the control.

Keywords: cultivars beans, gamma-irradiation, growth, leaf gas-exchange.

AIMS AND BACKGROUND

In physiological aspect, the problem of radiation contamination of the plant production has not been studied enough[1-4]. In a more general agroecological aspect what is insufficient is the study of radio-resistance of the different genotypes[5], which is extremely necessary for their recommendation for regions facing a real danger of radioactive contamination. There are almost no studies in this field with regard to beans.

The aim of the current study was to test the tolerance of young plants of two bean cultivars to gamma-irradiation stress, with regard to the growth, leaf gas exchange, and the content of plastid pigments. The use of two genotypes had for an object not only to record the cultivars peculiarities, but mainly to enlarge the knowledge regarding the crop reaction to irradiation stress.

* For correspondence.

EXPERIMENTAL

Dry bean seeds, the cultivars Plovdiv 10 and Plovdiv 11, were irradiated with gamma-rays Co^{60} with doses of 150 and 200 Gy. The irradiated and control seeds were superficially treated with a 1% (w/v) solution of $Ca(OCl)_2$ in a 10% (w/v) ethanol. The seeds germinated at a temperature of 22-24°C. Then, they were sown in plastic vessels with a capacity of 0.5 l, there were four seeds in each vessel, and this was repeated five times. The plants were grown as substrate crops in a climatic box till they became 30-day old under the following conditions: light intensity 200 μmol $m^{-2}s^{-1}$ (PAR), photo period 14 h (light) and 10 h (darkness), temperature of 22±2/20±2°C day/night and relative humidity of air 60-70%. On the 30th day of their development, the bean plants were analysed.

The plants analysis included:

1. Determination of the basic components of the classical growth analysis: relative growth rate (RGR), net assimilation rate (NAR), relative leaf area (LAR), specific leaf area (SLA), root weight ratio (RWR), steam weight ratio (SWR), leaf weight ratio (LWR), following the classical method of Poorter[6].

2. Determination of the leaf gas-exchange by means of a photosynthetic measuring system – LCA-4 (UK).

3. Determination of the content of the plastid pigments-spectrophotometrically following the method of Lichtenthaler[7].

Three separate experiments were carried out.

RESULTS AND DISCUSSION

The nature of the inhibition effect of the gamma-rays is revealed most completely by means of the growth analysis, the results of which are shown in Table 1 (for the cultivar Plovdiv 10) and in Table 2 (for the cultivar Plovdiv 11).

Table 1. Influence of gamma-rays on the basic indices of growth of young bean plants, the cultivar Plovdiv 10

Indices	0 Gy	150 Gy	200 Gy
RGR ($mg.g^{-1}.day^{-1}$)	0.086±0.005	0.064±0.005 (74)***	0.046±0.003 (53)***
LAR ($cm^2.g^{-1}$)	0.385±0.012	0.368±0.026 (95)	0.366±0.004 (92)*
NAR ($g.cm^{-2}day^{-1}$)	0.205±0.020	0.166±0.020 (81)*	0.122±0.040 (64)***
RWR (g(root).g^{-1} (plant))	0.221±0.009	0.203±0.020 (91)*	0.179±0.008 (80)*
SWR (g(stem).g^{-1}(plant))	0.241±0.030	0.240±0.040 (109)	0.286±0.006 (118)*
LWR (g(leaves).g^{-1} (plant))	0.488±0.006	0.492±0.020 (107)	0.478±0.053 (98)
SLA ($cm^2.g^{-1}.day^{-1}$)	0.799±0.026	0.802±0.031 (101)	0.704±0.029 (89)*
LA (cm^2)	164.21±2.68	141.14±3.61 (73)***	84.32±2.25 (50)***

* $p < 0.05$; ** $p < 0.01$ *** $p < 0.001$; in brackets – % difference from non-irradiated control.

300

It is evident that the applied irradiation doses inhibit RGR and this tendency is stronger at irradiation doses of 200 Gy for the seeds of both cultivars. RGR decreases by 47% in plants of the cultivar Plovdiv 10 and by 51% in the cultivar Plovdiv 11. The changes in NAR follow the tendency for RGR. More considerable is the inhibition in the cultivar Plovdiv 11 – 47% at irradiation dose of 200 Gy.

Table 2. Influence of gamma-rays on the basic indices of growth of young bean plants, the cultivar Plovdiv 11

Indices	0 Gy	150 Gy	200 Gy
RGR (mg.g^{-1}.day^{-1})	0.085±0.006	0.065 ±0.003 (76)**	0.042±0.002 (49)***
LAR (cm^2.g^{-1})	0.373±0.016	0.371±0.013 (99)	0.345±0.012 (92)
NAR (g.cm^{-2}.day^{-1})	0.227±0.011	0.175±0.012 (77)**	0.121±0.016 (53)***
RWR (g(root).g^{-1}(plant))	0.243±0.042	0.201±0.012 (78)*	0.150±0.021 (62)**
SWR (g(stem).g^{-1}(plant))	0.270±0.008	0.316±0.043 (117)	0.326±0.014 (120)***
LWR (g(leaves).g^{-1}(plant))	0.482±0.006	0.494±0.019 (102)	0.459±0.056 (95)
SLA (cm^2.g^{-1}.day^{-1})	0.771±0.012	0.750±0.017 (97)	0.710±0.029 (92)**
LA (cm^2)	142.14±3.59	121.12±4.19 (71)***	62.90±3.79 (45)***

$^{*}p < 0.05$; $^{**}p < 0.01$; $^{***}p < 0.001$; in brackets – % difference from non-irradiated control.

The distribution of the biomass in the plant organs of the two cultivars differs considerably. In the cultivar Plovdiv 11 the inhibition of RWR is with 16% greater than that in the cultivar Plovdiv 10. The results show that in both cultivars at the two irradiation doses this is at the expense of SWR (the correlation dry stem tissue/ dry plants tissue). The changes in LAR for plants of the two cultivars follow these in SLA and are analogous with RGR and NAR. The lower LAR values, according to us, are due to the enlarged leaf dry tissue, as a result of the decreased cell water content and the reduced leaf area (LA) – at irradiation doses of 200 Gy – 50% below the control in the cultivar Plovdiv 10 and 55% below the control in the cultivar Plovdiv 11.

When comparing the results from the two Tables it is evident that the cultivar Plovdiv 11 responses more strongly to gamma-irradiation, i.e. it is more sensitive than the cultivar Plovdiv 10, which, following these indices, is more tolerant to gamma-irradiation.

The analysis of the results of the NAR inhibition gives us a reason to presume that the processes of photosynthesis and respiration were disturbed in the plants subjected to gamma-irradiation stress. On the other hand, the changes in LAR and SLA (more considerable at doses of 200 Gy) indicate disturbances in the processes of water-exchange and stomato conductivity of plants, grown from seeds treated pre-sowingly with gamma-rays, a fact which motivates us to conduct studies in this respect.

The results of the changes in the leaf gas-exchange in the control and test plants for both cultivars are given in Table 3.

301

It is evident that in the plants of the two cultivars there is a tendency towards leaf gas-exchange slow down, which is more considerable at the higher irradiation dose of 200 Gy. The photosynthesis rate is inhibited by 33 % in the cultivar Plovdiv 10, and by 38% in the cultivar Plovdiv 11. One of the reasons for this may be the reduced transpiration intensity and the condition of the stomato apparatus.

The results in Table 3 show that with regard to the transpiration there is a similar tendency – at irradiation of the seeds with 200 Gy the transpiration is inhibited by 26% in the cultivar Plovdiv 10 and by 39% in the cultivar Plovdiv 11. This is the result of the suppressed growth of the root system and RWR, and hence the disturbed water supply and the stomata cells closure. In the plants of the first cultivar the stomata conductivity (g_s) is reduced by 28% at 150 Gy and by 34% at 200 Gy, and in plants of the second cultivar – by 38 and 50%, respectively.

Table 3. Photosynthesis rate (*A* – mmol $CO_2 m^{-2}s^{-1}$), transpiration intensity (*E* – µmol H_2O $m^{-2}s^{-1}$) and stomata conductivity (g_s – mol $m^{-2}s^{-1}$) in control and test plants

Indices	0 Gy		150 Gy		200 Gy	
	Plovdiv 10	Plovdiv 11	Plovdiv 10	Plovdiv 11	Plovdiv 10	Plovdiv 11
A	5.83+0.21	5.80+0.34	4.86±0.44 (81)*	4.70+0.19 (80)*	4.03±0.32 (67)***	3.76±0.20 (62)***
E	3.01±0.16	3.15±0.03	2.52±0.01 (86)***	2.6010.042 (88)***	2.25± 0.02 (74)***	2.02±0.06 (61)***
g_s	0.11	0.11	0.08 (72)	0.07 (62)	0.07 (66)	0.05 (50)

*$p < 0.1$; **$p < 0.01$; ***$p < 0.001$; in brackets – % difference from non-irradiated control.

Table 4. Plastid pigments content (mg/g fresh tissue) in leaves of young bean of plants, the cultivars Plovdiv 10 and Plovdiv 11

Indices	0 Gy		150 Gy		200 Gy	
	Plovdiv 10	Plovdiv 11	Plovdiv 10	Plovdiv 11	Plovdiv 10	Plovdiv 11
Chl. "a"	0.948±0.05	0.920±0.05	0.961±0.03 (101)	0.926±0.04 (101)	0.930+0.06 (96)	0.938±0.05 (101)
Chl. "b"	0.318±0.01	0.320±0.02	0.328±0.01 (102)	0.315±0.02 (98)	0.308±0.01 (95)	0.318±0.04 (99)
Carotinoids	0.322±0.02	0.340+004	0.326+0.02 (101)	0.348±0.07 (108)	0.319+0.02 (98)	0.362+0.04 (113)
Chl."a"+chl."b"	1.256	1.240	1.289	1.241	1.238	1.256
Chl."a"/chl."b"	2.984	2.876	2.840	2.939	3.106	3.414
Chls/carot.	3.920	3.677	3.941	3.600	3.867	3.414

In brackets – % difference from non-irradiated control.

The stomata closure is a well-known reaction of the plants in the case of water deficiency, aiming to diminish the loss of water. This undoubtedly has a negative effect on the photosynthesis rate, mainly as a result of the restricted access of CO_2 to the mesophyll cells.

Another possible reason for the reduced photosynthesis rate may be the changes in the concentrations of and the correlation between the plastid pigments, which participate in the light reactions of the photosynthesis.

302

The data on the changes in the plastid apparatus of young been plants, subjected to moderate and strong radiation stress (Table 4), indicate that for the both cultivars they do not differ considerably from the control.

This, according to us, is due to the fact that during the inhibition of the photosynthetic leaf area there occurs "a concentration" of the pigments per a unit biomass as a result of the increase of the leaves specific weight. Considerable differences in the correlation between them are not observed. The concentration and the correlations are within the norm and are not the reason for the observed tendency towards a decrease of the photosynthesis rate. This is probably due to the decreased LAR, and hence of SLA.

CONCLUSIONS

The gamma-rays, applied pre-sowingly to bean seeds of the cultivars Plovdiv 10 and Plovdiv 11, inhibit the growth of the young 30-day old plants, and it is more considerable at the higher irradiation dose. The inhibition of RGR is due mainly to the suppressed NAR and to a lesser degree to LAR.

The changes in the parameters of the leaf gas-exchange, characterising the physiological response of young bean plants to gamma-irradiation stress, have similar character for both cultivars. With regard to E and g_s, which in the cultivar Plovdiv 11 are suppressed to a greater degree, we have recorded considerable differences.

Considerable differences between the concentrations and the correlation between the plastid pigments are not observed.

There is cultivar sensitivity – the cultivar Plovdiv 10 is more tolerant to gamma-irradiation.

REFERENCES

1. R. CHOUBEY, J. L. TARAR: Annals of Plant Physiology, **4** (2), 133 (1990).
2. Y. S. LONG, D. Y. XU, Z. L. WAN: Journal of Southwest Agricultural University, **15** (2), 170 (1993) (12 ref.).
3. K. A. RABIE, S. A. SHENATA, M. A. BONDOK: Annals of Agric. Science. Cairo, **41** (2), 551 (1996).
4. SHI-JAN XIN: Journal of Southwest Agricul. University, **15**, (2), 157 (1993) (ref. 10).
5. F. H. NOFAL, M. A. NASSAR, M. U. EL-SGAR: Effect of Gamma-irradiation on Three Cultivars of Bean. Journal of Agric. Sciences, Mansoura Univ. Egypt, **19** (2), 561 (1995).
6. H. POORTER: Plant Growth Analysis: Towards a Synthesis of the Classical and the Functional Approach. Physiol. Plant., **75**, 237 (1989).
7. H. K. LICHENTHALER: In: Methods in Enzymology (Eds L. Posher, R. Doucce). Academic Press, New York, 148, 1987, 350-381.

Received 24 November 2000
Revised 5 February 2001

303